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1 Background

The Radioactive Liquid Waste Treatment Facility Upgrade Project (RLWTF-UP) will relocate, upgrade, and consolidate existing treatment capabilities that are currently housed in the Radioactive Liquid Waste Treatment Facility (RLWTF) at Technical Area 50, Building 001 (TA-50-001).

The Transuranic Liquid Waste (TLW) building is a new construction that will take place south of 50-001. Based on the design, it is estimated that the project will generate approximately 1,500 cubic yards of excess soil. There is minimal space near the project area to economically return the soil back to its point of origin. Offsite disposal at a radioactive disposal site is cost prohibitive.

The proposed scope is to remove and relocate the excess soil from the TLW construction site to the former wastewater treatment lagoons (i.e., surface impoundments) that are located at the east side of TA-35. In general, the depth of the excavation for the foundations is less than 10 feet, however, the area for the influent tanks will be approximately 20 feet deep at the SW corner of the building (Figure 1). The lagoons, which are cement lined and partially filled with sediment and vegetation, are Consent Order Sites 35-010(a)(b)(c) that were issued Certificates of Completion without Controls in 2011. No further investigation or remediation activities are planned for those sites. Some minor road improvements are expected to be made to access the TA-35 Lagoon area.

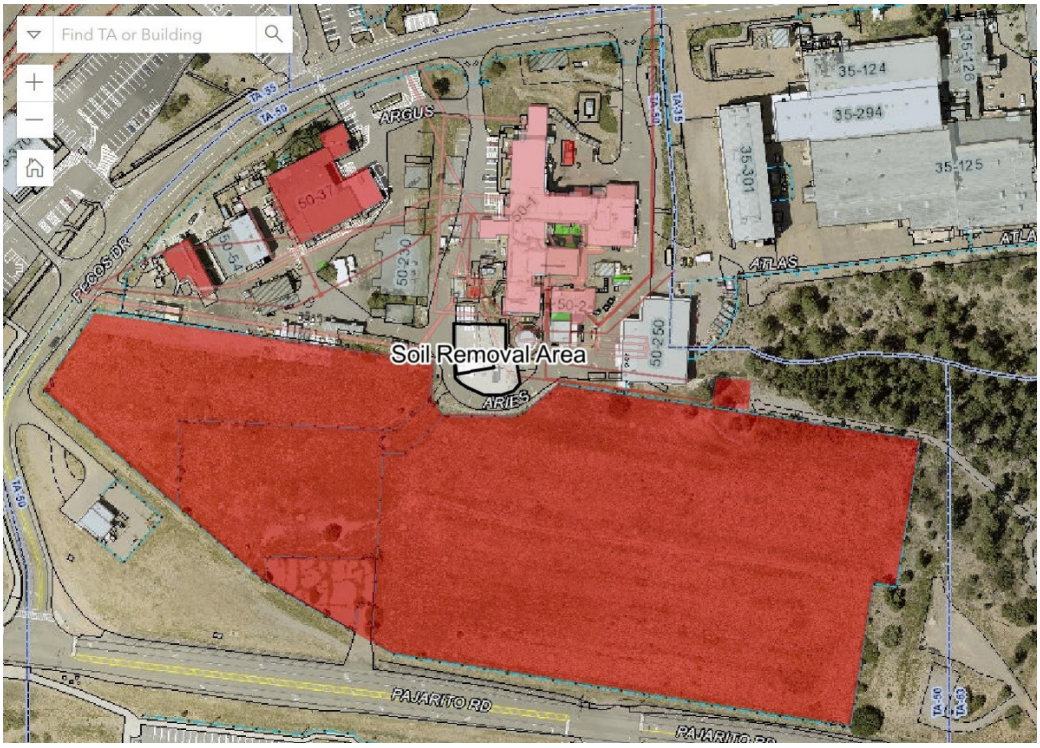

Figure 1. TLW Construction Site Location

1.1 Summary of Historical Evaluation of LANL Impact

1.1.1 Adjacent Properties with Known or Suspected Releases

The following summaries are excerpts from the Triad Potential Release Sites Database (prs.lanl.gov).

- SWMU 50-001(a) consists of the RLWTF, which treats low level wastewater from various parts of LANL. The RLWTF has operated continuously since its construction in 1963. The RLWTF primarily removes transuranic (TRU) elements using neutralization, flocculation and clarification, pH control, ion exchange filtration, and ultra- filtration on reverse osmosis processes. Treated effluent is monitored and discharged to a National Pollutant Discharge Elimination System (NPDES)-permitted outfall [SWMU 50-006(d)] in Mortandad Canyon. Associated with the RLWTF is a system of drain lines and tanks, which is used to transfer, treat, and temporarily store the liquid waste and treatment sludge. In July, 1990 core samples collected from boreholes drilled through the floor of TA-50-001, around the pH adjustment tank (also known as the grit chamber), determined that the inlet line to the pH adjustment tank had leaked.

- AOC 50-001(b) is the active underground drain line system through which liquid waste is transferred to the RLWTF. A manhole 50-72 is the central collection area for most incoming liquid waste. Three lines feed into manhole 50-072. In 1982, a major line connecting several TAs to this vault was constructed to replace an old line [consolidated unit 50-004(a)-00]. A single drain line carried all influent from manhole 50-72 into the grit tank at RLWTF until a leak around the grit tank was detected in 1990. The line now bypasses the grit chamber and passes through the neutralization chamber before it connects to the TA-50-002 tank vault [SWMU 50-002(a)].

  Four other waste lines run from TA-55 to TA-50-001 through structure 50-106 to tanks in an underground vault (structure 50-66). Soil sampling was scheduled to determine if contaminants had leaked from the pipes. According to the 1990 Solid Waste Management Unit (SWMU) report, there was some concern about contamination from the waste lines carrying TA-55 effluent because the original vacuum seals had lost their integrity. However, the drip pans have never collected fluid that showed the inner lines were leaking. The area where the lines run into TA-50-001 and the area west and north of the tank farm (TA-50-002) were sampled in August 1990. Sample results showed no radionuclides above background values (BVs).

- SWMU 50-004(a) consists of a former 520-ft section of the original 6-in.-diameter vitrified clay pipe that carried industrial waste to the RLWTF from Pajarito Road. This waste line was decommissioned and portions were removed in 1975. Acid waste line 45 [SWMU 50-004(c)] replaced the original SWMU 50-004(a) waste line to bypass the building 50-37 construction zone. Soil excavated during removal of the waste line was characterized for radioactive constituents and remediated to meet regulatory levels.

- SWMU 50-004(b) is the location of a decommissioned underground vault (structure 50-3) that housed three stainless-steel-lined concrete radioactive liquid waste storage tanks. The tanks ranged in volume from 1,000 to 4,500 gal. Waste lines to this tank vault included waste line 49 from TA-35 and waste line 50 from the RLWTF. Waste lines 49 and 50 are associated with SWMU 50-004(c). Waste line 49, the vault, and the tanks were removed in 1989.

- SWMU 50-004(c) consists of 13 former industrial waste lines (lines 44, 45, 45a, 46, 47, 48, 48a, 49, 54, 55, 56, 65, and 67) and three associated manholes (structures 50-6, 50-55, and 50-56) that discharged to the decommissioned underground tank vault (structure 50-3). With the exception of waste line 56, all waste lines and manholes associated with SWMU 50-004(c) were removed between 1981 and 1989. Waste line 56 remains in service; it connects a floor drain in Room 36 in building 50-1 to a 10-in. cast iron line that carries radioactive liquid waste (RLW) to the current tank farm (building 50-250). Radionuclide contamination encountered during decommissioning of the waste lines and manholes was remediated to regulatory levels through removal of the pipe and soil to approximately 19 ft below ground surface (bgs).

- SWMU 50-004(a) was a component of former Consolidated Unit 50-004(a)-00 along with SWMUs 50-004(b), and 50-004(c).
    - During the 1994 Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) conducted at:
        - SWMU 50-004(a), a 520-ft length of the original waste line trench was investigated; a 6-in. vitrified clay pipe and manholes were previously located in this trench. Eleven samples were collected from five boreholes advanced approximately 100 ft apart along the former waste line trench. Samples were submitted for analysis of target analyte list (TAL) metals, volatile organic compound (VOCs), semi-volatile organic compound SVOCs, polychlorinated biphenyl (PCBs), gamma spectroscopy, isotopic plutonium, and isotopic uranium.
        - SWMU 50-004(c), 67 samples were collected from 29 locations along the former waste line trenches and beneath the former manholes. Samples were submitted for analysis of TAL metals, VOCs, SVOCs, PCBs, gamma spectroscopy, isotopic plutonium, and isotopic uranium.

    - In 2003 and 2004, additional samples were collected at SWMUs 50-004(a) and 50-004(c) and analyzed for metals, gamma spectroscopy, isotopic plutonium, isotopic uranium, tritium, PCBs, pesticides, SVOCs, total petroleum hydrocarbons- diesel range organics (TPH-DRO), and VOCs.

    - The 2015 supplemental investigation report concluded the nature and extent of contamination have been defined and no further sampling for extent is warranted. This site does not pose a potential unacceptable risk or dose under the industrial, construction worker, or residential scenarios and poses no potential ecological risk.

- SWMU 50-006(a) is the location of two accidental operational releases of RLW at the head of Ten Site Canyon when a sump in a pumping station (building 50-2) overflowed, causing untreated wastewater to be discharged to waste lines 55 and 67 (the waste lines for treated effluent) and released at the head of Ten Site Canyon. The releases occurred in July and September 1974. In February 1975, waste line 67 was plugged at its outfall. A soil sample collected from the area impacted by the releases when waste line 67 was plugged showed elevated levels of gross-alpha radioactivity. Analysis of additional soil samples collected below

the waste line 67 outfall in September 1976 showed elevated levels of gross-alpha radioactivity extending 984 ft. down gradient of the outfall. In 1981, waste lines 55 and 67 were completely removed. During waste line removal, elevated levels of radionuclides, including plutonium-239, ruthenium-106, cesium-137, strontium-89, and yttrium-90, were detected. As a result, the release area was partially remediated by the removal of 70 cu meters of contaminated soil from the release area at the head of Ten Site Canyon.

During the 1993 Phase I RCRA RFI conducted at SWMU 50-006(a), 134 samples were collected from 53 locations below the former waste line outfalls, on both banks of the drainage channel, and in the Ten Site Canyon drainage channel at regular intervals over a distance of approximately 1,300 ft downstream from the eastern TA-50 boundary. Samples were submitted for analysis of TAL metals, VOCs, SVOCs, PCBs, amercium-241, gamma spectroscopy, isotopic plutonium, strontium-90, and tritium.

During the 1996 interim action (IA) implemented at SWMU 50-006(a), approximately 0.72 cu yds. of radioactively-contaminated soil was excavated and removed from the release area. Ten confirmation samples were collected from the excavated area and submitted for analysis of gross-alpha and gross-beta radioactivity. Data from the 1996 IA are screening level and showed residual gross-alpha levels above background, but meeting the IA cleanup level.

During the 2009 Phase I Consent Order investigation conducted at SWMU 50-006(a), eight samples were collected at three locations. Samples were submitted for analysis of TAL metals, nitrate, perchlorate, total cyanide, SVOCs, VOCs, PCBs, dioxins and furans, americium-241, gamma-emitting radionuclides, isotopic plutonium, isotopic uranium, strontium-90, and tritium.

Decision-level data collected at SWMU 50-006(a) and within Ten Site Canyon consists of results from 132 samples collected from 65 locations. Of this total, decision level data for SWMU 50-006(a) consists of results from 16 samples collected at 8 locations within the mesa top release area in 1993 and 2009. The remaining 116 samples are associated with Ten Site Canyon reaches TS-1W and TS-1C, which were evaluated separately as part of the Mortandad Canyon investigation. The 2015 supplemental investigation report concluded the nature and extent of contamination have been defined and no further sampling for extent is warranted. This site does not pose a potential unacceptable risk or dose under the industrial, construction worker, or residential scenarios and poses no potential ecological risk.

- SWMU 50-006(c) consists of the surface soil contamination at TA-50 resulting from the deposition of radioactive contaminants (primarily plutonium and americium) from historical stack emissions at TA-50. Emission sources include seven exhaust stacks that ventilated hoods for specific operations at the facility. A previous investigation showed slightly elevated plutonium levels in nearby soils. Buildings 50-1, 50-37, and 50-69 are monitored for radioactive emissions, and resulting data are reported to U.S. Environmental Protection Agency (EPA) Region 6.

  The Environmental Restoration (ER) Project conducted an RFI at SWMU 50-006(c) in the summer of 1993 to determine the nature and extent of any radionuclides and hazardous constituents. The RFI also included AOCs 50-007 and 50-008, potential surface soil contamination from airborne releases from the incinerator complex (Building 50-37) and the volume reduction

facility (Building 50-69). This SWMU and these AOCs were investigated as an aggregate because their boundaries are indistinguishable. Samples were collected from surface soils from five unpaved areas around Buildings 50-1, 50-37, and 50-69. Sample locations were biased toward natural drainage channels, and soil samples were collected from a total of 51 locations. The samples were analyzed for inorganic and organic chemicals, PCBs, and radionuclides. Analytical results showed elevated concentrations of beryllium, cadmium, chromium, nickel, and silver near a pipe rack. Because the pipe rack was still in use at the time of the RFI, the RFI report recommended that the area be re-characterized when the pipe rack was removed. In addition, cobalt-60, radium-226, several PAHs, and PCBs (Aroclor-1254) were detected above their respective BVs and/or screening levels.

- SWMU 50-006(d) was identified in the 1990 SWMU Report as an ongoing operational release of treated effluent from the RLWTF to Effluent Canyon from an associated drain line (structure 50-64) and associated NPDES-permitted Outfall 051. Effluent Canyon is a tributary of Mortandad Canyon. Data from effluent samples collected in the early 1980s showed inorganic chemical and radionuclides present above background levels. In 1985, the EPA Region 6 issued an administrative order to the Department of Energy (DOE) requiring modification of the outfall to mitigate ongoing stream-bank erosion caused by the discharge pipe ending 25 ft short of the Mortandad Canyon stream channel. DOE extended the pipe into the stream channel. No discharges to Outfall 051 have occurred since November 2010; however, the outfall is still is permitted under the LANL's NPDES industrial and sanitary Permit, NM0028355 and may be used in the future to discharge treated effluent.

  During the 1993 Phase I RCRA RFI conducted at SWMU 50-006(d), 52 samples were collected from 27 locations in the canyon down gradient of the SWMU 50-006(d) outfall. Samples were submitted for analysis of SVOCs, PCB, gamma-emitting radionuclides, isotopic plutonium, isotopic uranium, strontium-90, and tritium. Data from the 1993 RFI are decision level.

  During the 2009 Phase I Consent Order investigation, 40 samples were collected at 17 locations below the outfall, in the drainage, and along the drain line. Samples were submitted for analysis of TAL metals, nitrate, perchlorate, total cyanide, SVOCs, VOCs, PCBs, dioxins and furans, gamma-emitting radionuclides, isotopic plutonium, isotopic uranium, strontium-90, and tritium.

  Decision-level data for SWMU 50-006(d) and reach E-1E consists of results from 92 samples collected at 44 locations. Of this total, decision-level data for SWMU 50-006(d) consists of results from 40 samples collected at 17 locations in 1993 and 2009. The remaining 52 samples are associated with Effluent Canyon reach E-1E, which were evaluated separately as part of the Mortandad Canyon investigation and were used only to define lateral extent of potential contamination associated with SWMU 50-006(d). The 2015 supplemental investigation report concluded the nature and extent of contamination have been defined except the vertical extent of americium-241 and cesium-137. This site does not pose a potential unacceptable risk under the industrial, construction worker, or residential scenarios and poses no potential ecological risk. The site also poses no potential unacceptable dose under the industrial scenario. However, the site does pose a potential unacceptable dose to construction worker and residential receptors.

- AOC 50-007 is a former incinerator complex that was housed in Building 50-37. The incinerator complex was constructed in 1975 and consisted of the incinerator, various waste-feed components, and two waste-feed tanks. The incinerator complex was equipped with an off-gas treatment unit, and the exhaust air system from the incinerator included two HEPA filters. Liquid effluent generated by the off-gas aqueous scrub system was filtered to remove solids before transfer to a double instrument-monitored pipeline to the RLWTF. From 1978 to 1987, 23 test burns were successfully conducted for RCRA and Toxic Substances Control Act (TSCA) wastes. EPA issued a permit for the incineration of PCBs in 1984, and NMED included the incinerator in a 1989 hazardous waste facility permit (HWFP). Actual waste streams incinerated after the permits were issued included radioactively contaminated PCBs and scintillation cocktails. Operation of the incinerator was discontinued in 1987 to allow for system upgrades. The incinerator was removed and underwent RCRA closure in 1998.

  A previous investigation showed slightly elevated plutonium levels in nearby soils.

- AOC 50-008 consists of the volume reduction facility [now called the waste characterization, reduction, and repackaging facility (WCRRF)] located in Building 50-69. This facility was constructed in 1979 to size-reduce large TRU-contaminated metallic items (e.g., glove boxes, metal ducts) and repackage them into standard-sized containers for ultimate disposal at Waste Isolation Pilot Plant (WIPP). The facility was first used in 1982. No outfalls are associated with Building 50-69. All liquid wastes are processed at the RLWTF. A previous investigation showed slightly elevated plutonium levels in nearby soils.

- AOC 50-010 is a former vehicle decontamination bay that was located in Room 34B of the RLWTF. The area was used to clean radioactive contamination from vehicles and large objects used to transport RLW to TA-50. Liquid wastes generated during decontamination activities were transferred to tanks at Building 50-2 through a floor drain and waste line. The decontamination bay was operated from 1963 through October 1999. It was enclosed in 1983. There is no documented evidence of contaminant releases from this facility.

1.2 Preliminary Results from Surveys for Residual Contamination

Preliminary data was taken from soil surface samples collected in TA-50. The summary statistics in Table 1 show that the soil concentrations are at nominal background levels except for Am-241 and Pu-239. Comparisons of soil concentrations show that all radionuclide concentrations are several orders of magnitude below residential soil concentrations corresponding to 1 mrem/yr dose.

Table 1. Raw data used for preliminary analysis (Intellus 2020)

Field Sample ID	Date Sampled	Isotope	Result (pCi/g)
AAA3153	06-24-1993	Americium-241	0.016
AAA3155	06-24-1993	Americium-241	0.009
AAA2797	06-16-1993	Americium-241	0.081
AAA3242	07-14-1993	Americium-241	0.054
AAA2798	06-16-1993	Americium-241	0.292
AAA3243	07-14-1993	Americium-241	0.054

Field Sample ID	Date Sampled	Isotope	Result (pCi/g)
AAC0280	11-07-1994	Plutonium-239/240	0.11
AAA2439	05-19-1993	Plutonium-239/240	0.016
AAA2440	05-19-1993	Plutonium-239/240	0.014
AAA2441	05-19-1993	Plutonium-239/240	0.072
AAA2442	05-19-1993	Plutonium-239/240	0.069
AAA2447	05-19-1993	Plutonium-239/240	0.206
AAA2448	05-19-1993	Plutonium-239/240	0.171
AAA2449	05-19-1993	Plutonium-239/240	0.021
AAA2450	05-19-1993	Plutonium-239/240	0.002
AAA2453	05-19-1993	Plutonium-239/240	0.015
AAA2455	05-19-1993	Plutonium-239/240	0.031
AAA2456	05-19-1993	Plutonium-239/240	0.041
AAA2458	05-19-1993	Plutonium-239/240	0.066
AAA2459	05-19-1993	Plutonium-239/240	0.691
AAA2460	05-20-1993	Plutonium-239/240	0.055
AAA2461	05-20-1993	Plutonium-239/240	0.456
AAA2462	05-20-1993	Plutonium-239/240	0.121
AAA2463	05-20-1993	Plutonium-239/240	0.094
AAA2464	05-20-1993	Plutonium-239/240	0.791
AAA2465	05-20-1993	Plutonium-239/240	0.615
AAA2466	05-20-1993	Plutonium-239/240	0.285
AAA2491	05-20-1993	Plutonium-239/240	0.275
AAA2467	05-20-1993	Plutonium-239/240	0.744
AAA2468	05-20-1993	Plutonium-239/240	0.023
AAA2469	05-20-1993	Plutonium-239/240	1.606
AAA2470	05-12-1993	Plutonium-239/240	0.097
AAA2471	05-12-1993	Plutonium-239/240	0.001
AAA2475	05-12-1993	Plutonium-239/240	0.049
AAA2476	05-12-1993	Plutonium-239/240	0.763
AAA2477	05-12-1993	Plutonium-239/240	0.13
AAA2478	05-20-1993	Plutonium-239/240	0.316
AAA2479	05-20-1993	Plutonium-239/240	0.023
AAA2480	05-20-1993	Plutonium-239/240	0.027
AAA2481	05-20-1993	Plutonium-239/240	0.162
AAA2482	05-20-1993	Plutonium-239/240	0.187
AAA2483	05-20-1993	Plutonium-239/240	0.076
AAA2484	05-20-1993	Plutonium-239/240	0.027
AAA2485	05-20-1993	Plutonium-239/240	1.395
AAA2486	05-20-1993	Plutonium-239/240	0.435
AAA2487	05-20-1993	Plutonium-239/240	0.017
AAA2488	05-20-1993	Plutonium-239/240	0.012

Field Sample ID	Date Sampled	Isotope	Result (pCi/g)
AAA2489	05-20-1993	Plutonium-239/240	0.126
AAA2519	06-01-1993	Plutonium-239/240	0.053
AAA2520	06-01-1993	Plutonium-239/240	0.058
AAA2523	06-01-1993	Plutonium-239/240	3.83
AAA3153	06-24-1993	Plutonium-239/240	0.052
AAA3155	06-24-1993	Plutonium-239/240	0.023
AAA2797	06-16-1993	Plutonium-239/240	0.39
AAA3242	07-14-1993	Plutonium-239/240	0.417
AAA2798	06-16-1993	Plutonium-239/240	2.91
AAA3243	07-14-1993	Plutonium-239/240	0.593
CAMO-09-10032	06-30-2009	Plutonium-239/240	0.0473
CAMO-09-9962	06-30-2009	Plutonium-239/240	0.0158
MD50-03-50895	03-20-2003	Cesium-137	0.01
MD50-03-51116	03-21-2003	Cesium-137	0.008
MD50-03-51117	03-21-2003	Cesium-137	0.003
CAMO-09-9962	06-30-2009	Cesium-137	-0.0163
CAMO-09-9963	06-30-2009	Cesium-137	0.00494
CAMO-09-9964	06-30-2009	Cesium-137	-0.0192
CAMO-09-10032	06-30-2009	Cesium-137	0.0575
AAC0280	11-07-1994	Uranium-238	0.71
AAA2439	05-19-1993	Uranium-238	0.953
AAA2440	05-19-1993	Uranium-238	0.982
AAA2441	05-19-1993	Uranium-238	1.502
AAA2442	05-19-1993	Uranium-238	1.28
AAA2447	05-19-1993	Uranium-238	1.313
AAA2448	05-19-1993	Uranium-238	1.153
AAA2449	05-19-1993	Uranium-238	1.228
AAA2450	05-19-1993	Uranium-238	1.053
AAA2453	05-19-1993	Uranium-238	1.141
AAA2455	05-19-1993	Uranium-238	0.897
AAA2456	05-19-1993	Uranium-238	0.836
AAA2458	05-19-1993	Uranium-238	0.901
AAA2460	05-20-1993	Uranium-238	0.822
AAA2461	05-20-1993	Uranium-238	1.103
AAA2467	05-20-1993	Uranium-238	1.489
AAA2468	05-20-1993	Uranium-238	1.254
AAA2469	05-20-1993	Uranium-238	0.966
AAA2470	05-12-1993	Uranium-238	0.934
AAA2471	05-12-1993	Uranium-238	0.841
AAA2475	05-12-1993	Uranium-238	1.037

Field Sample ID	Date Sampled	Isotope	Result (pCi/g)
AAA2476	05-12-1993	Uranium-238	1.02
AAA2478	05-20-1993	Uranium-238	1.405
AAA2479	05-20-1993	Uranium-238	0.855
AAA2480	05-20-1993	Uranium-238	1.062
AAA2481	05-20-1993	Uranium-238	1.204
AAA2482	05-20-1993	Uranium-238	0.919
AAA2483	05-20-1993	Uranium-238	1.375
AAA2484	05-20-1993	Uranium-238	1.405
AAA2485	05-20-1993	Uranium-238	1.049
AAA2486	05-20-1993	Uranium-238	1.118
AAA2487	05-20-1993	Uranium-238	1.323
AAA2488	05-20-1993	Uranium-238	1.147
AAA2489	05-20-1993	Uranium-238	1.195
CAMO-09-10032	06-30-2009	Uranium-238	0.98
CAMO-09-9962	06-30-2009	Uranium-238	0.989
AAC0280	11-07-1994	Uranium-235/236	0.03
AAA2439	05-19-1993	Uranium-235/236	0.051
AAA2440	05-19-1993	Uranium-235/236	0.082
AAA2441	05-19-1993	Uranium-235/236	0.087
AAA2442	05-19-1993	Uranium-235/236	0.079
AAA2447	05-19-1993	Uranium-235/236	0.065
AAA2448	05-19-1993	Uranium-235/236	0.062
AAA2449	05-19-1993	Uranium-235/236	0.091
AAA2450	05-19-1993	Uranium-235/236	0.07
AAA2453	05-19-1993	Uranium-235/236	0.103
AAA2455	05-19-1993	Uranium-235/236	0.083
AAA2456	05-19-1993	Uranium-235/236	0.029
AAA2458	05-19-1993	Uranium-235/236	0.027
AAA2460	05-20-1993	Uranium-235/236	0.059
AAA2461	05-20-1993	Uranium-235/236	0.05
AAA2467	05-20-1993	Uranium-235/236	0.063
AAA2468	05-20-1993	Uranium-235/236	0.06
AAA2469	05-20-1993	Uranium-235/236	0.076
AAA2470	05-12-1993	Uranium-235/236	0.067
AAA2471	05-12-1993	Uranium-235/236	0.034
AAA2475	05-12-1993	Uranium-235/236	0.083
AAA2476	05-12-1993	Uranium-235/236	0.092
AAA2478	05-20-1993	Uranium-235/236	0.099
AAA2479	05-20-1993	Uranium-235/236	0.079
AAA2480	05-20-1993	Uranium-235/236	0.043
AAA2481	05-20-1993	Uranium-235/236	0.013

Field Sample ID	Date Sampled	Isotope	Result (pCi/g)
AAA2482	05-20-1993	Uranium-235/236	0.046
AAA2483	05-20-1993	Uranium-235/236	0.046
AAA2484	05-20-1993	Uranium-235/236	0.077
AAA2485	05-20-1993	Uranium-235/236	0.095
AAA2486	05-20-1993	Uranium-235/236	0.039
AAA2487	05-20-1993	Uranium-235/236	0.055
AAA2488	05-20-1993	Uranium-235/236	0.085
AAA2489	05-20-1993	Uranium-235/236	0.093
AAA2519	06-01-1993	Uranium-235/236	0.037
AAA2520	06-01-1993	Uranium-235/236	0.056
AAA2523	06-01-1993	Uranium-235/236	0.079
CAMO-09-10032	06-30-2009	Uranium-235/236	0.0632
CAMO-09-9962	06-30-2009	Uranium-235/236	0.0686
AAC0281	11-07-1994	Uranium-234	0.65
0550-95-5001	10-05-1995	Uranium-234	0.662
CAMO-09-9963	06-30-2009	Uranium-234	0.778
CAMO-09-9964	06-30-2009	Uranium-234	0.705
AAA2443	05-19-1993	Uranium-234	0.722
AAA2444	05-19-1993	Uranium-234	1.072
AAA2445	05-19-1993	Uranium-234	0.703
AAA2446	05-19-1993	Uranium-234	0.768
AAA2451	05-19-1993	Uranium-234	0.771
AAA2452	05-19-1993	Uranium-234	0.989
AAA2490	05-19-1993	Uranium-234	0.927
AAA2472	05-12-1993	Uranium-234	1.204
AAA2473	05-12-1993	Uranium-234	1.162
AAA2474	05-12-1993	Uranium-234	1.017
AAC0280	11-07-1994	Uranium-234	0.75
AAA2439	05-19-1993	Uranium-234	0.835
AAA2440	05-19-1993	Uranium-234	0.866
AAA2441	05-19-1993	Uranium-234	1.321
AAA2442	05-19-1993	Uranium-234	1.136
AAA2447	05-19-1993	Uranium-234	1.186
AAA2448	05-19-1993	Uranium-234	1.189
AAA2449	05-19-1993	Uranium-234	1.146
AAA2450	05-19-1993	Uranium-234	0.911
AAA2453	05-19-1993	Uranium-234	1.06
AAA2455	05-19-1993	Uranium-234	0.848
AAA2456	05-19-1993	Uranium-234	0.869
AAA2458	05-19-1993	Uranium-234	0.786
AAA2470	05-12-1993	Uranium-234	0.935

Field Sample ID	Date Sampled	Isotope	Result (pCi/g)
AAA2471	05-12-1993	Uranium-234	0.706
AAA2475	05-12-1993	Uranium-234	1.185
AAA2476	05-12-1993	Uranium-234	1.065
AAA2519	06-01-1993	Uranium-234	1.122
AAA2520	06-01-1993	Uranium-234	1.378
AAA2523	06-01-1993	Uranium-234	1.692
CAMO-09-10032	06-30-2009	Uranium-234	0.891
CAMO-09-9962	06-30-2009	Uranium-234	0.777

Table 2. Summary of preliminary data and comparisons to background and Soil Release Concentration (SRCs). Measurements are in units of pCi/g.

	Am-241	Cs-137	Pu-239	U-238	U-235	U-234
Mean	0.08	0.007	0.36	1.10	0.06	0.97
STD	0.11	0.025	0.70	0.20	0.02	0.23
Max	0.292	0.0575	3.83	1.502	0.103	1.692
min	0.009	-0.0192	0.001	0.71	0.013	0.65
95% UCL [a]	0.433	0.0254	0.92	1.153	0.0706	1.032
Background [b]	0.013	1.65	0.054	2.29	0.20	2.59
Residential SRC 1 mrem/yr [c]	13	1.65	16	8	2	28

[a] Upper confidence Level (UCL)

[b] Inorganic and Radionuclide Background Date for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory; LA-UR-98-4847; R. T. Ryti, P. A. Longmire, D. E. Broxton, Steven L. Reneau, and E. V. Mcdonald

[c] The 1 mrem/yr Soil Release Concentrations were derived by taking the residential Authorized Limit from LANL 2016 and dividing by 25.

1.3 Conclusions Regarding the Classification of the TLW Construction Site Relative to Potential for Residual Radioactive Contamination

There are properties adjacent or near to the TLW construction site that are either contaminated or have emitted radionuclides historically, and the preliminary data suggest LANL impact. Thus, residual contamination may exist on the TLW construction site that was deposited from activities conducted by neighboring LANL operations from the 1970s through the present. However, the soil concentrations of radionuclides from the preliminary set of measurements suggest that general levels are likely to be substantially below residential SRC and near background levels. Based on this assessment, the TLW construction site qualifies as a Class 3 area under MARSSIM (i.e., potentially impacted with concentrations of residual radioactive material in soils elevated, but likely to be below thresholds for the intended land uses and close to background levels (MARSSIM 2000). The Class 3 designation is modified further by the projected on-site land use.

1.4 Preliminary Results for Hazardous Constituent Contamination

Maximum detected results for hazardous waste constituents from previous sampling events associated with nearby SWMUs/AOCs are shown in Table 3. No results approached hazardous waste toxicity

characteristic regulatory levels. Some results were above background levels and NMED's recommended Residential Soil Screening Levels (SSLs), but none were above other SSLs.

Table 3. Summary of preliminary chemical data and comparisons to background and Soil Screening Levels (SSLs). Measurements are in units of mg/kg.

Constituent	Soil BV (mg/kg)	Qbt 2, 3, 4 BV (mg/kg)	Industrial SSL (mg/kg)	Construction Worker SSL (mg/kg)	Residential SSL (mg/kg)	Maximum Result
Arsenic	8.17	2.79	21.5	57.4	4.25	6.5 (J-)
Barium	295	46	255,000	4,390	15,600	81.9
Beryllium	1.83	1.21	2,580	148	156	1.5
Cadmium	0.4	1.63	1,110	72.1	70.5	0.63 (J)
Chromium	19.3	7.14	505	134	96.6	30.8
Total Cyanide	0.5	0.5	63.3	12.1	11.2	3.97
Lead	22.3	11.2	800	800	400	11.8
Selenium	1.52	0.3	6,490	1,750	391	1.14 (UJ)
Acetone			960,000	242,000	66,300	0.0174 (J)
Chrysene			3,230	23,100	153	0.0379
Di-n-butylphthalate			91,600	26,900	6,160	0.0755 (J)
Fluoranthene			33,700	10,000	2,320	0.475
Indeno(1,2,3-cd)pyrene			32.3	240	1.53	0.17
Toluene			61,300	14,000	5,230	0.000000282
Trichloroethene			36.5	6.9	6.77	0.000434 (J)

1.5 Conclusions Regarding the Classification of the TLW Construction Site Relative to Potential for Hazardous Constituent Contamination

As a best management practice, samples of excess soil to be transported to the TA-35 lagoons will be collected and analyzed prior to excavation. The samples will be analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), organic pesticides, organic herbicides, PCBs (Arochlors), total metals (TAL), total cyanide, and total petroleum hydrocarbons (both gasoline and diesel range organics). Analytical results should confirm previous findings, ensure the soil is indeed below SSLs, and demonstrate that the soil qualifies as administrative fill for land application at TA-35.

If during sampling, odors or visual staining is observed, additional samples will be collected for petroleum hydrocarbons. Table 4 shows the chemical analytical methods that will be utilized.

Table 4: Chemical Analytical Methods	
Volatile Organic Compounds	SW-846:8260B
Semi-volatile Organic Compounds	SW-846:8270D
Organic Pesticides	SW-846:8081B
Organic Herbicides	SW-846:8151A
PCBs (Arochlors)	SW-846:8082
Total Metals	SW-846:6020
Total Cyanide	SW-846:9012A
TPH-Gasoline Range Organics	SW-846:8015M_PURGEABLE
TPH-Diesel Range Organics	SW-846:8015M_EXTRACTABLE

2 Data Quality Objectives for Sampling and Analysis Plan

The sampling and analysis plan (SAP) for the TLW construction site follows procedures EPC-ES-TP-0238, "Dose Assessment Data Quality Objectives for Land Transfers into the Public Domain" (LANL 2019) and AP-P409-0303, "Waste Sample and Analysis Plan Procedure" (LANL 2021).

2.1 Objectives of the SAP

The primary objective of this sampling and analysis plan is to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in soils in the TLW construction site soil is documented, in appropriate units, and is below the SRCs. SRCs are provided in Table 2. The secondary objective of this sampling and analysis plan is to confirm, within the stated statistical confidence limit, that the mean levels of chemical constituents in the soil are below SSLs outlined by NMED.

2.2 Decision Identification

The principle study question is: Does the residual radioactive contamination exceed the SRCs in the area within the TLW construction site?

- If results from the soil radioactive contamination measurements are at or above the SRCs (collectively), the soil is not a candidate for relocation.
- If results from the soil radioactive contamination measurements are below the SRCs (collectively), the site is a candidate for relocation.

The secondary study question is: Do the residual chemical constituent concentrations exceed the SSL in the area within the TLW construction site?

- If results from the soil chemical contamination measurements are at or above the SSLs (collectively), the soil is not a candidate for relocation.
- If results from the soil chemical contamination measurements are below the SSLs (collectively), the site is a candidate for relocation.

2.3 Inputs into the Decision

The assumed near-term future land use and exposure pathway assumes residential use. SRCs used for all the radionuclides analyzed are provided in Table 2. SLLs used for the hazardous constituent determination are provided in Table 3.

Data used in the radionuclide analysis include preliminary surface soil concentration measurements contained in Table 1.

The unity rule will be applied because there are multiple radionuclides in the analysis. The formula used in for the unity rule is:

$$\frac{C_1}{AL_1} + \frac{C_2}{AL_2} + \frac{C_3}{AL_3} \cdots \frac{C_n}{AL_n} \leq 1 \qquad \text{(eqn.1)}$$

where $C_{1\text{-}n}$ and $AL_{1\text{-}n}$ are the upper-bound estimates of the mean concentrations for radionuclides (e.g., upper 95% values) and Authorized Levels 1 through n, respectively.

2.4 Study Boundaries

The study is limited to TA-50 TLW construction site soil, as identified in Figure 1. As concluded from historical information and previous soil sampling, the list of radionuclides in the analysis include Am-241, Cs-137, Pu-239, U-234, U-235, and U-238. Individual doses are evaluated out to 1000 years. The list of hazardous constituents of concern based on previous sampling include VOCs, SVOCs, PCBs, and total metals.

2.5 Decision Rules

The radioactive contamination decision rule is based on the null hypothesis that the mean residual contamination levels in soil and/or sediment in TLW construction site soil combined over all radionuclides is likely to result in an all-pathway radiation dose to the critical receptor above 1 mrem yr^{-1}. The alternative hypothesis is that the mean residual contamination levels in soil and/or sediment in TLW construction site soil combined over all radionuclides is not likely to result in an all- pathway radiation dose to the critical receptor above 1 mrem yr^{-1}.

The chemical contamination decision rule is based on the null hypothesis that the mean residual contamination levels in soil in TLW construction site soil are below their respective NMED Residential SSL.

The acceptable statistical errors for this analysis are that Type I error (i.e., conclude contamination levels at site are < AL when in fact it is > AL) has a probability of $p < 0.05$; and the Type II error (i.e., conclude soil contamination level is > AL when in fact it is < AL) has a probability of $p < 0.1$. Normality of the distribution for the preliminary data is not assumed.

2.6 Optimization of Design Process

The survey design is optimized by analyzing historical information data. The preliminary data suggest there is evidence of impact from LANL operations though the soil concentrations are expected to be substantially lower than the SRCs and SSLs. Thus, the TLW construction site soil will be treated as a Class

3 area. If land use requirements change in the future, sampling could be targeted to the specific area of the proposed activity.

2.7 Statistically-Based Evaluation for Number of Samples Required using MARSSIM

The TLW Project provided a map of the TLW construction site, which was then incorporated into Visual Sampling Plan (VSP) software (Matzke et al. 2010). The approximate boundary of the area was then delineated as a sampling area (Figure 2). The MARSSIM application within VSP was then used to determine the statistically-based sampling plan. The preliminary sampling data in Table 1 was used to determine the standard deviations needed for calculating the needed number of samples for each of the identified radionuclides. All sampling locations were randomly determined.

Figure 2. Delineated sample area

2.8 Instrumentation and Measurement Quality Objectives

The main objectives are to determine appropriate analysis techniques for each radionuclide and hazardous constituent and ensure Measurement Quality Objectives are satisfied. One should be confident that the measurement results are valid and appropriate for the decisions being made.

2.8.1 Measurement Quality Objectives:

- Detection Capability: Minimum Detection Concentration (MDC) should be below the MARSSIM defined Lower Bound of the Gray Region (LBGR).
- The degree of measurement uncertainty (combined precision and bias) should be reported and the level should be reasonable relative to the needed accuracy of the decision and accounted for in the statistical analysis.
- Range of the instrument and measurement technique should be appropriate for the concentrations expected.
- The instrument and measurement technique should be specific for the radionuclide(s) and/or hazardous constituent being measured. Specificity is the ability of the measurement method to measure the radionuclide of concern in the presence of interferences.
- For field instruments, the instrument should be rugged enough to consistently provide reliable measurements. However, in this case, all samples will be analyzed in the laboratory.

- Ensure soil samples obtained for hazardous constituent analysis are taken in an acceptable manner for analysis per US EPA SW846 Analytical Methods.

2.8.2 Procedures used to meet these measurement quality objectives:

1) Collection of valid soil sample appropriate for the dose assessment,
   a. Sampling of soil will be done using LANL (2019b) procedure EPC-ES-TP-003 "Soil and Vegetation sampling for the Environmental Surveillance Program." These are surface soil samples appropriate for the deposition pathway and the exposure scenario (i.e., top 5 cm), and subsurface soil samples (1.4-4 m).
   b. All sampling for hazardous constituents will be performed in accordance with LANL Waste Management Services (WM-SVS) Sampling and Analysis Manual, WM-SVS-MAN-001 and the EPC-WMS-QP-210 Sampling and Analysis Procedure, which uses protocols outlined in US EPA RCRA Waste Sampling Draft Technical Guidance.
2) Soil sample analysis using appropriate EPA approved analytical procedures for each radionuclide and hazardous constituent. The following will be used by the independent laboratory:
   a. Environmental Measurements Laboratory (EML). The procedures manual of the Environmental Measurements Laboratory. Report HASL-300; 1997. Radionuclide specific procedures for the radionuclides of Am-241, Pu-239 and U- 238 are provided in EML (EML 1997).
   b. Environmental Protection Agency (EPA). Method 901.1 - Gamma Emitting Radionuclides in Drinking Water: Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from NTIS, document no. PB 80-224744.
   c. Environmental Protection Agency (EPA) SW-846 Method 6010C or 6020 – Inductively Coupled Plasma – Atomic Emission Spectrometry. Method of analysis for determining total metal components (TAL Metals) in a solid sample.

After the measurements are completed, the laboratory results in units equivalent to the ALs will be evaluated with respect to the MQOs, as stated above.

2.9 Statistical Evaluation of the Survey Results

All the applicable data that has passed the MQO evaluation will be used to determine the upper- bound estimate of the mean for soil concentrations (generally, the 95% value) for each radionuclide. The EPA software ProUCL (EPA 2015) will be used to determine this value. The statistical decision as to whether the residual soil contamination levels (i.e., the 95% UCLs) are below the SRCs will be evaluated using the following criteria. All analyses and results will be documented.

Decision Criteria:

1) When evaluating individual sample results, if all samples are SRC, then no further action is required and the site passes the criteria for recreational occupation. Additionally, if all samples are ≤ the NMED SLLs, then no further action is required and the site passes the criteria for Industrial, Construction Worker, and Residential purposes. No further actions are needed.
2) If all individual samples or the UCL are > the SRC, then the site is not a candidate for release and site remediation is needed, followed by resampling before it can be released.

3) If the UCL is below the SRC but some individual measurements are above the SRC, then statistical analysis is needed. Generally, non-parametric statistical approaches are used to evaluate the null hypothesis. If contamination is present in background, the Wilcoxon Rank Sum test is suggested, and if contamination is not present in background or very low relative to the SRC, use the Sign Test. For TLW construction site soil, the Sign Test will be used with a $p < 0.05$ decision threshold for significance. See MARSSIM chapter 8 for details and examples.
4) Alternatively, one could confirm that the ratio of the upper-confidence level (UCL) of the average concentration divided by the AL and the sum of hot spot activity ratios do not exceed 1, as show in Equation 2.

$$\frac{\bar{C}_{UCL}}{C_{SRC}} + \sum_{i=1}^{n} \frac{C_{i,C>AF}}{C_{SRC} * AF} \leq 1 \qquad \text{(eqn. 2)}$$

Here $\bar{C}_{UCL}$ is the 95% upper bound estimate of the concentration mean, C_{AL} is the residential soil concentrations corresponding to 1 mrem/yr dose, $C_{i,c>AL}$ is the sample concentration for a single sample above the AL (i.e., has elevated measured concentrations), and *AF* is the Area Factor [ratio of effective dose calculated for area of contamination normalized to effective dose calculated for 10,000 m^2 (RESRAD default)]. If value in eqn. 2 is > 1, the site is a candidate for further characterization of the nature and extent of the contamination, remediation of the site, follow up confirmatory sampling, and reanalysis against the decision criteria in this section. Area Factors are dependent on the exposure scenario and should be calculated individually.
5) If there are multiple radionuclides (i) being evaluated in a sampling unit, the sum of the ratios should be less than or equal to 1, as shown in eqn. 1.
6) The dose assessment based on the soil measurements will include the sum of doses from all radionuclides, and this sum will be compared to the 3 mrem/yr threshold for follow up ALARA analysis.

3 Results of the Analysis for Sampling Number and Locations

The specific details of the analysis using MARSSIM and the results are provided in Attachment 1 of this report. Results showed that 11 randomly-sited samples were needed, this sampling plan doubles the number of samples to account for the excavation depth. The approximate locations are drawn on Figure 3. Approximately 11 samples are surface (5 cm) and 11 samples are at depth (maximum depth of auger 1.5-4 m).

Figure 3. Approximate sample locations

Locations were randomly selected using a quasi-random number generator for x and y coordinates (Matzke et al. 2014). The specific statistical parameter values, analysis, results, and approximate coordinates for the randomly selected sampling locations are provided in the summary report (Attachment 1).

4 References

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ATTACHMENT 1

Systematic sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated number of samples	9
Number of samples adjusted for EMC	9
Number of samples with MARSSIM Overage	11
Number of samples on map [a]	14
Number of selected sample areas [b]	1
Grid pattern	Triangular

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid gives the linear and square dimensions of the grid used to systematically place samples. If there was more than one sample area, this represents the largest dimensions used.

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

VSP offers many options to determine the locations at which measurements are made or samples are collected and subsequently measured. For this design, systematic grid point sampling was chosen. Locating the sample points systematically provides data that are all equidistant apart. This approach does not provide as much information about the spatial structure of the potential contamination as simple random sampling does. Knowledge of the spatial structure is useful for geostatistical analysis. However, it ensures that all portions of the site are equally represented. Statistical analyses of systematically collected data are valid if a random start to the grid is used.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{S_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,

$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is 1-α,

$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is 1-β.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

For each nuclide in the table, the values of these inputs that result in the calculated number of sampling locations are:

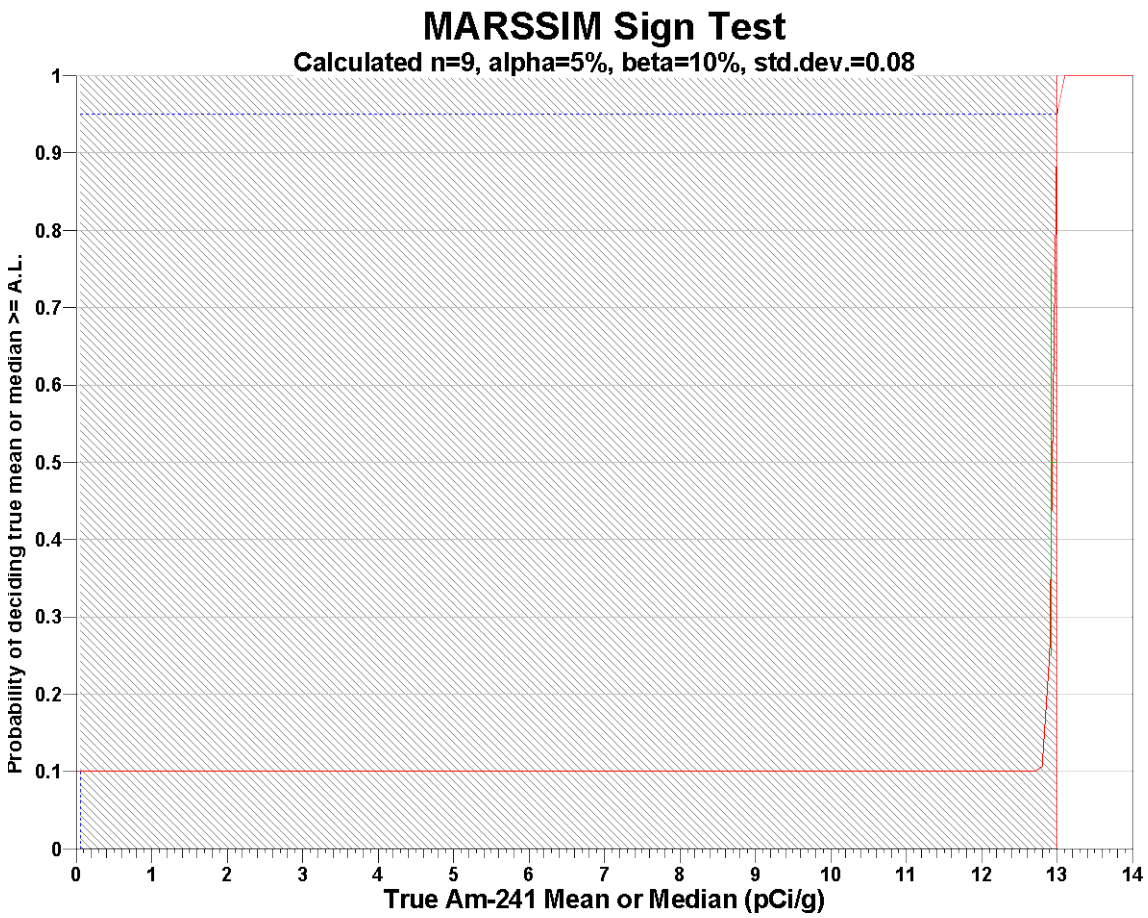
Nuclide	n[a]	n[b]	n[c]	Parameter					
				S_{total}	Δ	α	β	$Z_{1-\alpha}$ [d]	$Z_{1-\beta}$ [e]
Am-241	9	9	11	0.11	12.92	0.05	0.1	1.64485	1.28155
Cs-137	9	9	11	0.025	1.643	0.05	0.1	1.64485	1.28155
Pu-239	9	9	11	0.7	15.64	0.05	0.1	1.64485	1.28155
U-324	9	9	11	0.23	27.03	0.05	0.1	1.64485	1.28155
U-235	9	9	11	0.02	1.94	0.05	0.1	1.64485	1.28155
U-238	9	9	11	0.2	6.9	0.05	0.1	1.64485	1.28155

[a] The number of samples calculated by the formula.
[b] The number of samples increased by EMC calculations.
[c] The final number of samples increased by the MARSSIM Overage of 20%.
[d] This value is automatically calculated by VSP based upon the user defined value of α.
[e] This value is automatically calculated by VSP based upon the user defined value of β.

Performance

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that $\mu >$ action level and alpha (%), probability of mistakenly concluding that $\mu <$ action level. The following table shows the results of this analysis.

Number of Samples							
AL=13		α=5		α=10		α=15	
		s=0.22	s=0.11	s=0.22	s=0.11	s=0.22	s=0.11
LBGR=90	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=80	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=70	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Note: Values in table are not adjusted for EMC.